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COMPARISON OF THE AIRFLOW CHARACTERISTICS
OF SEVERAL AIRCRAFT CARRIERS
(Title Unclassified)

by

William F. Barnett and Herbert E. White

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DAVID TAYLOR MODEL BASIN
UNITED STATES NAVY
WASHINGTON, D. C.

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OF SEVERAL AIRCRAFT CARRIERS

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SUMMARY

A comparison of the airflow characteristics of several aircraft carriers has been made with a view toward establishing correlations between configuration and airflow. The objective is the development of an understanding of the carrier airflow problem that could lead to improved configurations. Results show that, while causal relationships can be seen for specific configurations, prediction of the flow about one carrier from a knowledge of another is not very successful.

INTRODUCTION

The effect of airflow around aircraft carriers on flying operations has been of concern since the advent of the USS LANGLEY. The increasing interest in cross-wind operations has now enlarged the area of concern.

Numerous surveys of the airflow patterns about various carriers have been conducted, both in full scale and model scale. The greater part of these efforts was concerned with defining the flow about existing carriers. Recently, however, there has been an increasing interest in studying the flow problem from a different standpoint. This new interest is directed toward considering the airflow problem during the design of new carriers, and making changes of configuration to improve the airflow properties.

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In order to achieve the desired improvements, it will first be necessary to define the airflow characteristics that are to be sought. Then, it will be necessary to determine, by model tests, the configuration changes necessary to achieve these characteristics. These changes can then be weighed in the light of the many other considerations involved in the design; and, where possible, the changes can be incorporated into the carrier. A significant step in this direction has been taken in the program currently underway with CVA 67.

This report attempts to define what characteristics of the airflow pattern are desirable or acceptable from a flight operations standpoint, and to determine from available data what correlations of airflow pattern and carrier shape can be made. An attempt is also made to determine whether the flow about a new carrier can be estimated from a knowledge of flow patterns of existing carriers, and to determine whether changes of carrier geometry can be suggested to improve airflow patterns.

SOURCES OF DATA

The sources of data discussed here are the results of wind-tunnel tests conducted by the Aerodynamics Laboratory and full-scale observations and measurements by the Naval Air Test Center (NATC), Patuxent River, and by Bendix Aviation Corporation. (See References 1 through 9.)

The wind-tunnel data consist of surveys of local dynamic pressure at various points in the wake of models of about 1/100-scale. The NATC data consist principally of pilot observations, and the Bendix data are measurements of wind speed and direction on the flight decks of several aircraft carriers. The models tested are shown in Figures 1 through 6.

For convenience of comparison, selected data were compiled and plotted and are presented in Figures 7 through 15. Wind-tunnel data are available for the CVA 62, CVA 64, CVA 65, CVS 36, and CVB 41 (References 1 through 6). The full-scale observations and measurements used here were taken aboard the CVA 61 (Reference 7).

DISCUSSION

Interest in airflow conditions in the vicinity of an aircraft carrier has been provoked by the reported undesirable effects of rough

air on flight operations. It is important first to define what characteristics of the airflow are desirable from the standpoint of a pilot traversing the affected region. At least three characteristics may be seen to be of major importance. First, the over-all average change in airspeed (usually a loss) should be a minimum. Secondly, variations of airspeed and flow direction with small changes of aircraft position should be minimized. Thirdly, variations of the flow pattern with small changes of ambient wind direction should be kept as small as possible.

COMPARISON OF CONFIGURATIONS CVA 62, CVA 64, AND CVA 65

When the cross-wind component of relative wind is zero, the flow patterns about the CVA 62 and CVA 64 are quite similar (Figure 7). This might be expected, because the hulls are alike, the flight decks are about the same width, and the island shapes are similar (Figure 1). Evidently the different fore-and-aft island positions of the two carriers do not cause a significant change in airflows at this wind angle. The airflow pattern of the CVA 65, on the other hand, is quite different from that of the other two carriers.

The wider island of the CVA 65 causes a larger area of decreased dynamic pressure ratio in the wake. This area is not centered directly downwind of the island, but spreads out to port, combining with an area of reduced dynamic pressure ratio evidently associated with the port flight deck overhang. This causes a large area of reduced dynamic pressure across the flight deck. Each of these three carriers exhibits a depression of dynamic pressure to port, evidently caused by the flight deck overhang.

At a yaw angle of 10° (relative wind approximately down the center of the angled deck), correlations between the carrier shapes and airflow patterns are not apparent (Figure 8). The most striking feature is the sharp change in dynamic pressure ratio across the center line of the deck of the CVA 62 and CVA 64, particularly at small distances aft of the trailing edge of the deck.

At a yaw angle of 20° , the flow patterns for the CVA 64 and CVA 65 are similar (Figure 9). The flow pattern for the CVA 62 is different from the others, and more irregular. The two factors that probably

account for the similarity of flow patterns of the CVA 64 and the CVA 65 at this angle are these: the frontal area (normal to the wind) of the island of the CVA 64 is about the same as that of the island of the CVA 65 and the fore-and-aft position of the island, which becomes significant in locating the island wake, is about the same on the two carriers.

In an attempt to more completely define the airflow pattern about the CVA 65, some additional tests were conducted in the wind tunnel by the Aerodynamics Laboratory. Local directions of flow were determined, in addition to the local dynamic pressure ratios, and are presented in Figure 10. The variation of dynamic pressure ratios along a 3° glide path with relative wind down the angled deck is shown in Figure 10a, in which four stations aft of the flight-deck trailing edge are superimposed for easy comparison. The variation along a parallel plane 10 feet above the glide path is also presented. This figure vividly shows the variation in dynamic pressure encountered by the approaching aircraft. Particularly significant is the depression in the vicinity of 114 feet.

The local flow directions presented in Figure 10b are for the same positions and conditions. It can be seen that extreme variations are encountered. The local dynamic pressure ratios obtained during the directional measurements do not check the original data, so far as magnitudes are concerned, but the shapes of the dynamic pressure ratio profiles do correlate well.

Comparing the data from the CVA 62, CVA 64, and CVA 65 surveys shows that correlations between the carrier shape and airflow pattern can be established to some extent. Certain features of the various flow patterns can be attributed to particular features of the carriers. However, it is also shown that in some cases these correlations are impossible; for example, at $\psi = 10^\circ$. The results of the angularity measurements on the CVA 65 indicate that angularity can be a significant factor and that a complete picture of the airflow pattern should include angularity data.

COMPARISON OF STRAIGHT AND ANGLED DECKS

The wind-tunnel data for the CVS 36 provide an opportunity for comparing the airflow pattern of a straight-deck configuration with the airflow about an angled deck, with the hull configuration remaining unchanged.

The comparison (Figure 11) shows that the two configurations have very similar flow patterns. Comparative data were available for only $\psi = 0^\circ$ and $\psi = 10^\circ$. The data at $\psi = 0^\circ$ (not presented) also show considerable similarity of the two wakes.

The limited data available indicate that the type of flight deck does not greatly affect the characteristics of the wake. However, it must be considered that the deck overhang of more modern carriers is considerably larger than that of the CVS 36, and conclusions drawn for the earlier carrier may not be valid when applied to more modern configurations.

COMPARISON OF THE CVB 41 AND CVS 36 STRAIGHT DECK

In Figure 12 a comparison is shown between two straight-decked carriers of generally similar configuration but different size. The larger of the two, the CVB 41, has a somewhat smaller and weaker wake than the smaller CVS 36. The data, however, are rather meager for extensive comparison. The comparison of these two carriers, based on similarity of shape and size, seems to point out the significance of the fact that less obvious features are responsible for considerable interference in air wake and pattern.

EFFECT OF WIND DIRECTION

Figure 13 shows the effect of varying wind direction on the airflow about one of the carrier models for a station 550 feet aft of the trailing edge of the deck. This typical plot shows the radical change in pattern due to change in relative wind. Figure 14 presents a part of the results of an anemometer survey about 6 feet above the flight deck and in the vicinity of the yardarm of the USS RANGER (CVA 61). These results show the sensitivity to local wind direction in certain areas to changes in ambient wind direction. It also gives an indication of the amount of variation of ambient wind over short periods of time.

The example of the effect of relative wind direction may be considered typical, so far as the magnitude of changes is concerned. The full-scale surveys of wind direction demonstrate the large changes of ambient wind direction that can occur in a short period of time. It will be seen that having an acceptable airflow pattern at one angle of wind-over-deck is not in itself an ideal situation, if the pattern changes radically with the small changes of ambient wind that can occur over a short period of time.

EFFECT OF ISLAND

The tests of the CVA 62, CVA 64, and CVA 65 provided some opportunity for the observation of the effects of various island configurations on airflow. However, in these cases, other variations of carrier shape were also present. Only one direct comparison of the same configuration with and without island was possible from the data available. These data, from a wind tunnel survey of the CVB 41, are presented in Figure 15. A lowered dynamic pressure ratio is present to starboard with the island installation. Without the island, the pattern is approximately symmetrical.

From the data taken from the CVA 62, CVA 64, and CVA 65 tests, and the conventional and flush-deck configurations of the CVB 41, it can be seen that the island does have an effect on the airflow, as would be expected. However, it is also apparent that this effect is not necessarily detrimental, and a large island is not necessarily worse than a small one. In some cases, the reduction of dynamic pressure ratio caused by the island tends to "flatten out" the profile of dynamic pressure ratio.

FULL-SCALE OBSERVATIONS

The NATC observations indicate that an updraft occurs in the landing patterns of several carriers and at a variety of wind directions (References 8 and 9). In most cases the upstream updraft occurs close to the carrier; however, in some cases, this updraft is as far aft of the carrier as 1000 to 2000 feet. The wind-tunnel measurements of dynamic pressure have indicated that the airflow at this distance aft is approaching initial free-stream conditions. It is possible that heat from the carrier may contribute to this updraft, a condition not simulated in the wind tunnel. It is expected that if an updraft is present, it will be small; however, even a small updraft might be noticeable if the pilot enters from undisturbed air.

The sensation of updraft that pilots experience in the region close to the carrier could be caused by flying from an area of low dynamic pressure to an area of higher dynamic pressure.

GENERAL CONCLUSIONS

Correlations between major features of carrier geometry and airflow patterns can be established. However, less salient features of the geometry can affect the flow patterns to a considerable extent, so that prediction

of the flow characteristics of a new configuration cannot be made reliably.

The variations of flow direction are of significant magnitude to be considered, and measurements of flow direction should be included in surveys of the airflow patterns.

The variation of relative wind direction due to variations in the ambient wind is large enough to cause significant changes in the flow patterns of the carriers surveyed.

Wind-tunnel testing of models does not completely simulate full-scale conditions because of the effects of heat input from the carrier, and the effect of tunnel-boundary restraint.

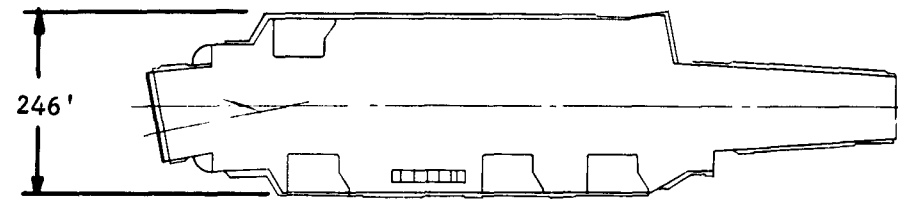
To optimize the carrier configuration from an airflow standpoint, a wind tunnel program could be established wherein the effects of each carrier component could be investigated separately. This type of testing would utilize various components from which carrier models with various hull lines, islands, flight decks, and other features could be constructed. Each major component could be varied in shape or location to achieve the optimum airflow conditions. Of course, the ideal configuration from airflow considerations may be unacceptable for other reasons.

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David Taylor Model Basin
Washington, D. C.
May 1963

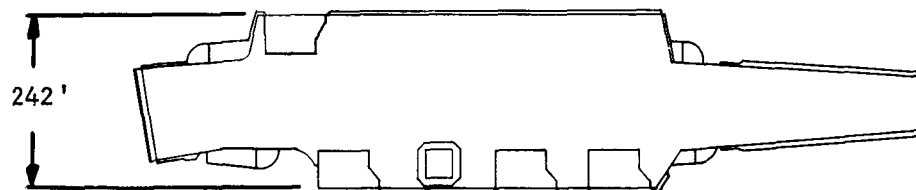
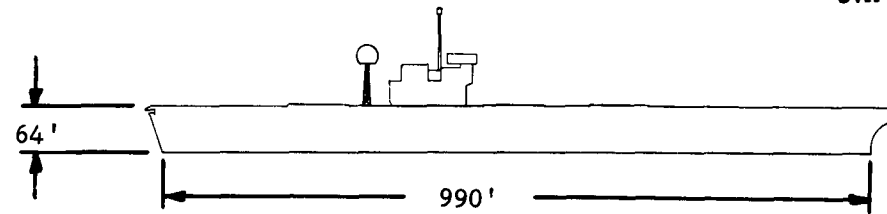
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Wash., Jun 1959. 19 l. incl. illus. (David Taylor Model Basin.
Aero Rpt. 955, Pt. 2) CONFIDENTIAL

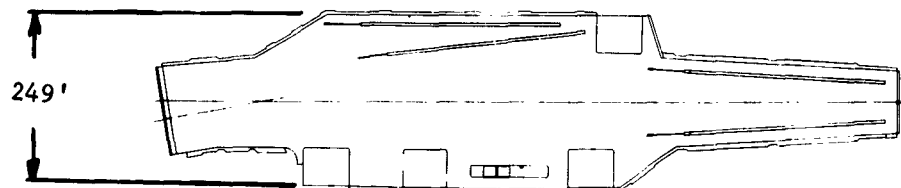
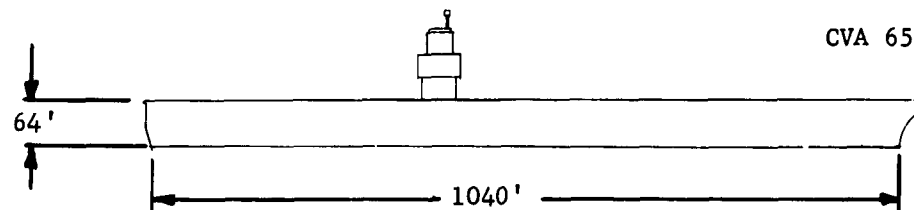
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CVA 64



CVA 65



CVA 62

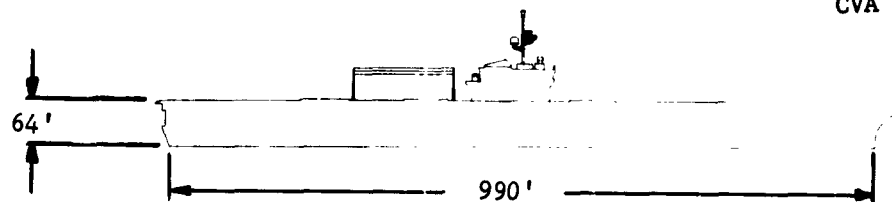


Figure 1 - General Arrangement of the Models
(a) CVA 62, CVA 64, and CVA 65

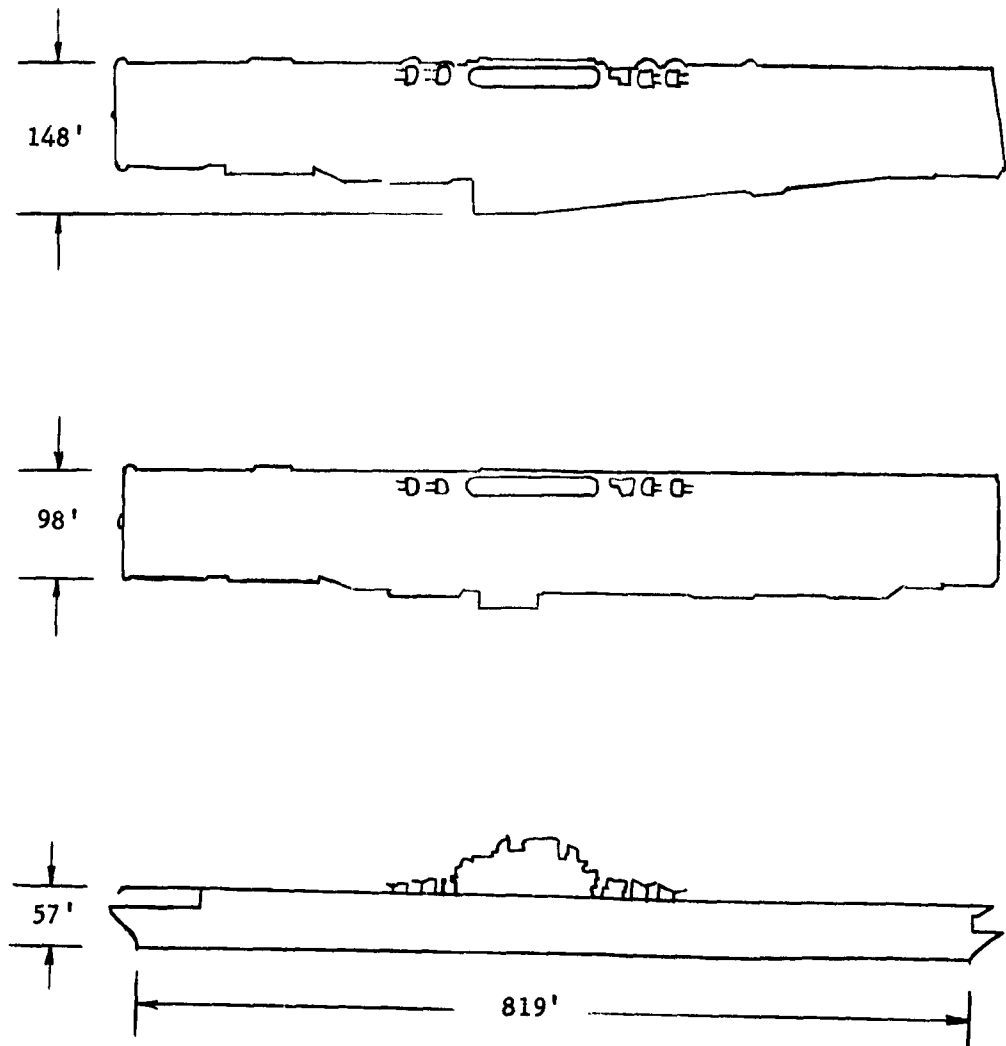


Figure 1 (Continued)

(b) The Straight-Deck and Angled-Deck
Configurations of the CVS 36 Model

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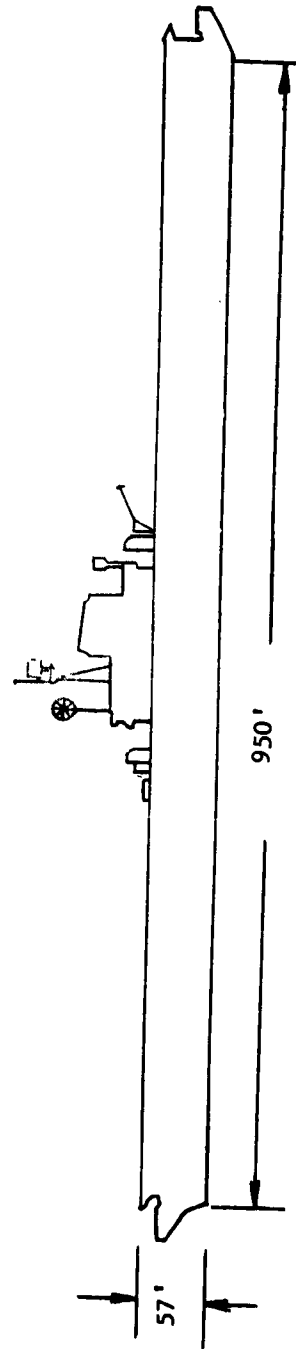
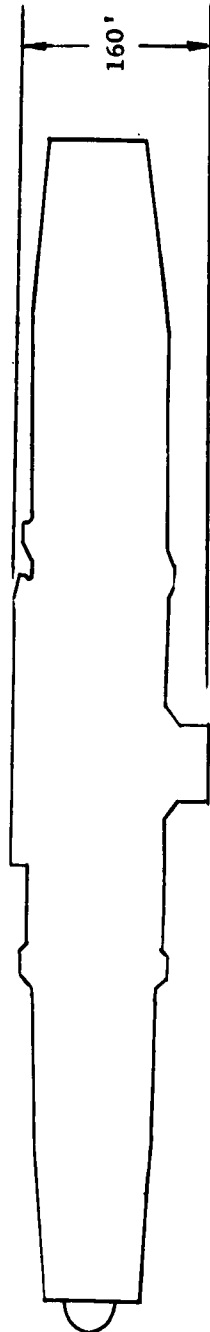


Figure 1 (Concluded)
(c) The CVB 41 Model

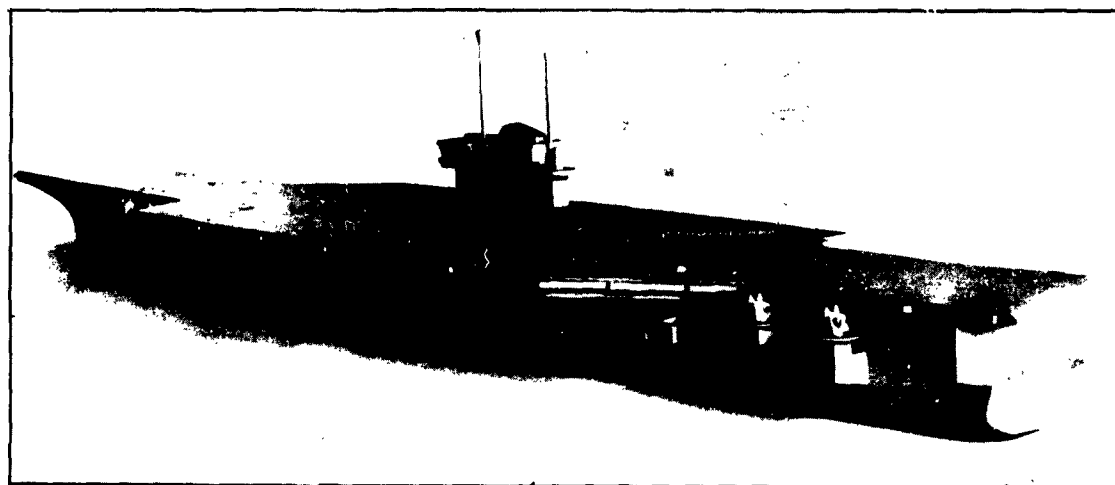


Figure 2 - Three-Quarter Rear View of the CVA 62 Carrier Model

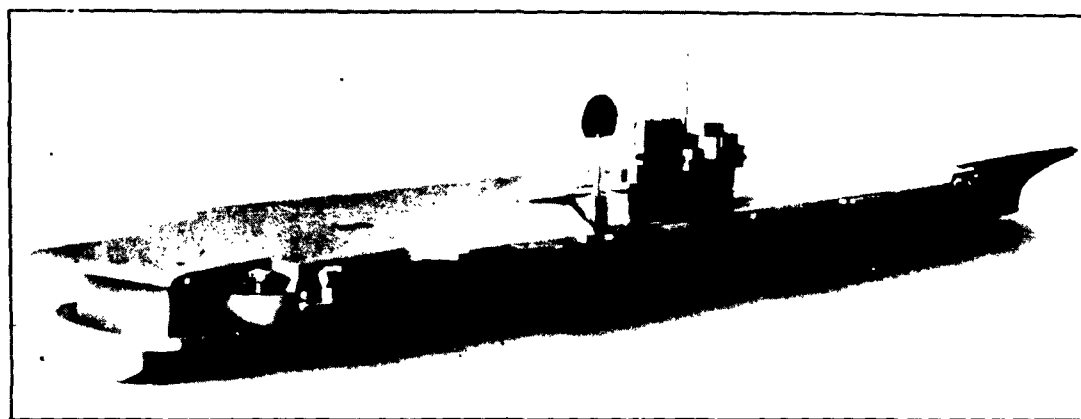


Figure 3 - Three-Quarter Rear View of the CVA 64 Carrier Model

PSD-68,504

May 22, 1957

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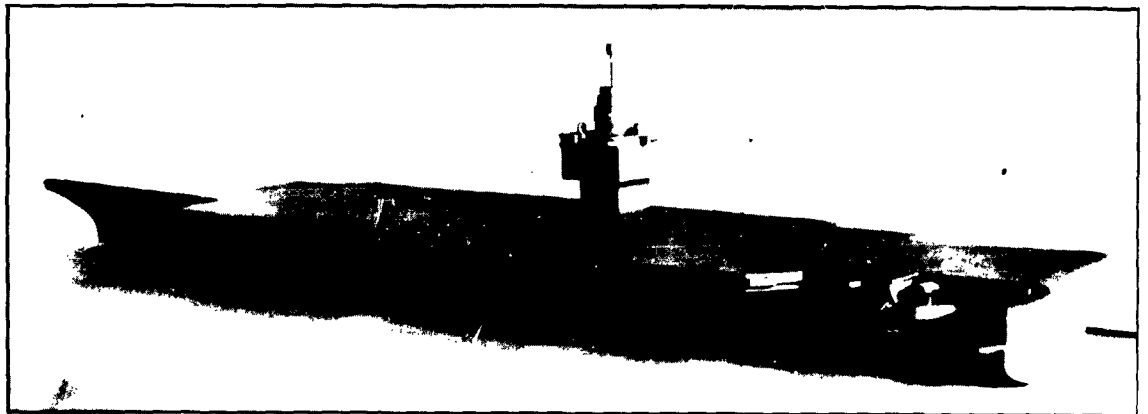


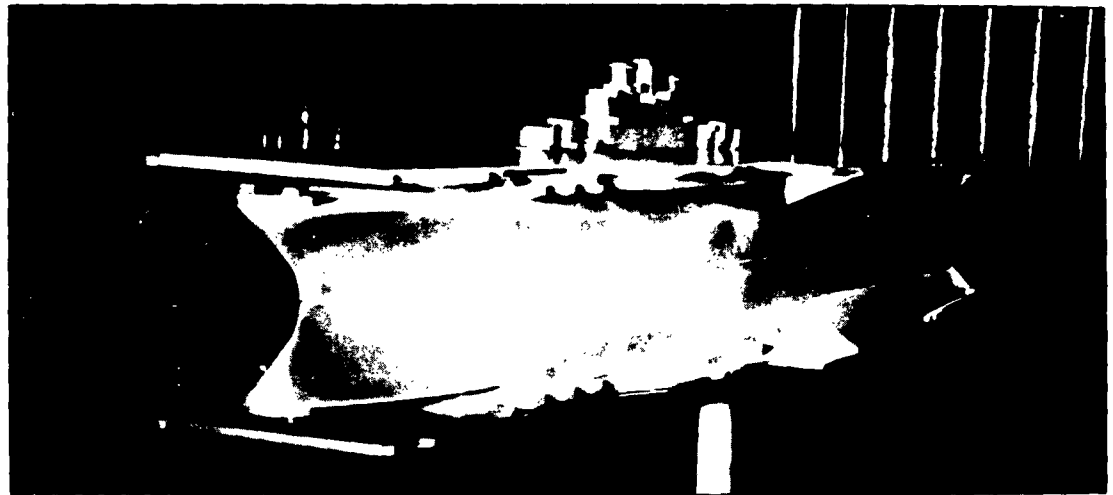
Figure 4 - Three-Quarter Rear View of the CVA 65 Carrier Model



NP21-55,927

November 1, 1954

(a) Straight Deck



NP21-55,385

December 18, 1953

(b) Angled Deck

Figure 5 - Straight and Angled Deck Configurations of the
CVS 36 Model With Mirror Image Models

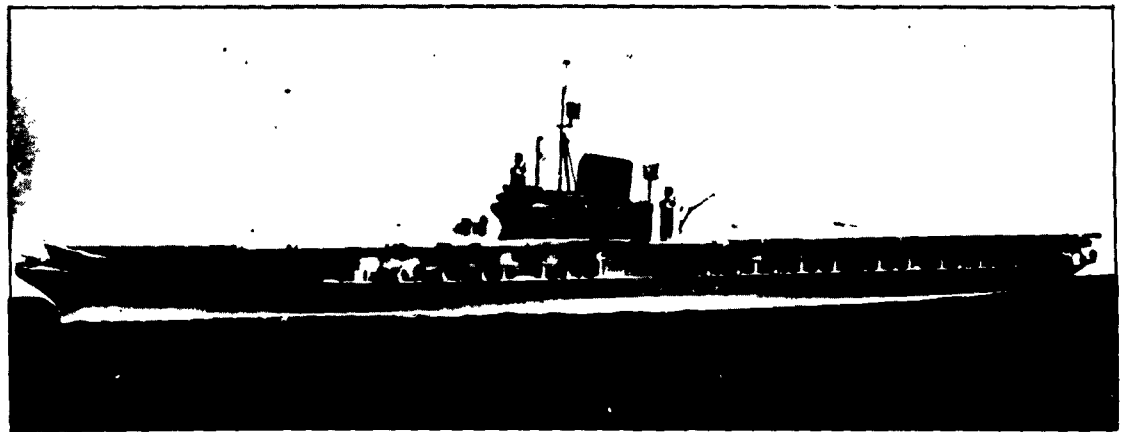


Figure 6 - Side View of the CVB 41 Carrier Model

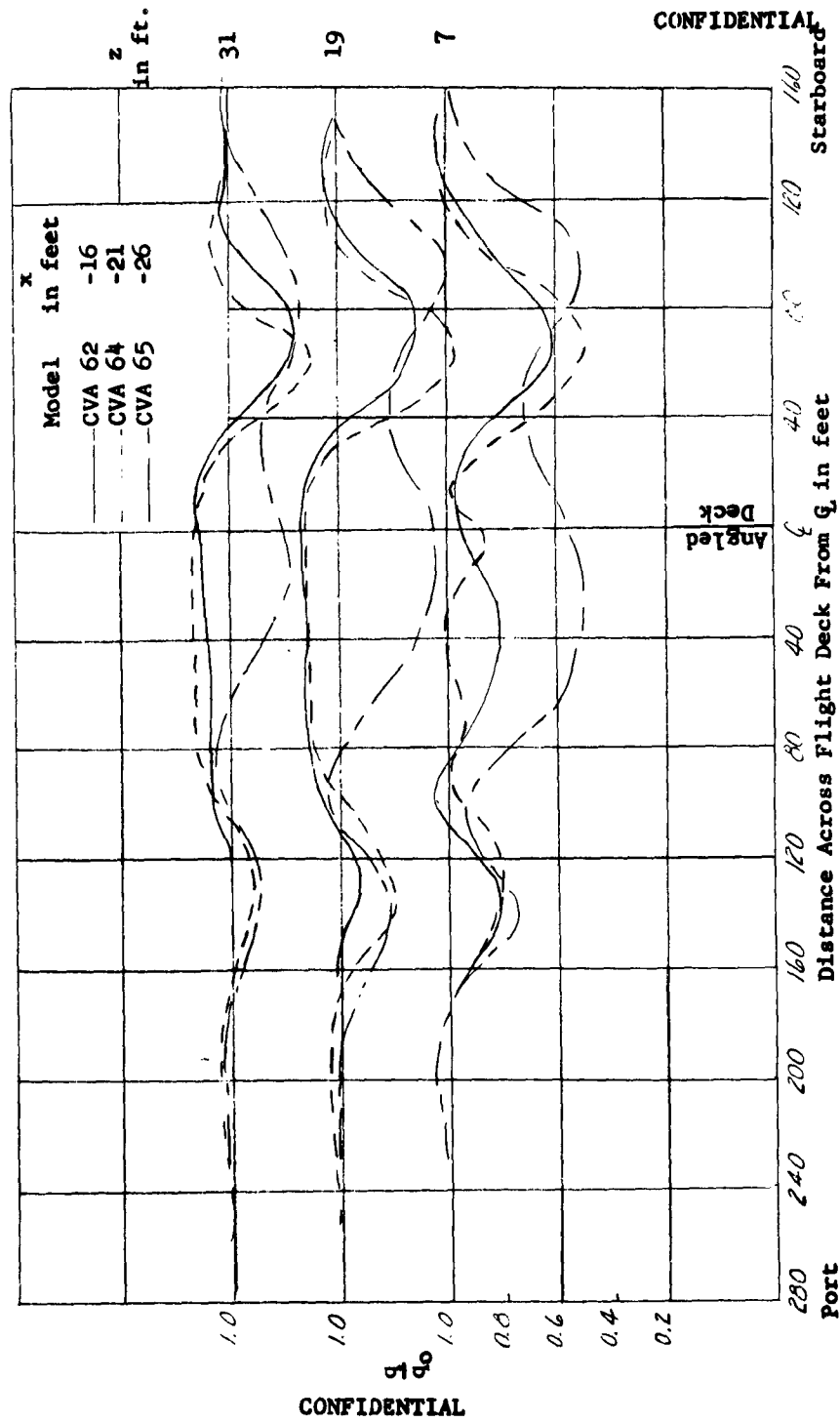


Figure 7 - Dynamic Pressure Ratios in the Wakes of Three Aircraft Carriers
With Relative Wind Aligned With Ship Center Line ($\psi = 0^\circ$)

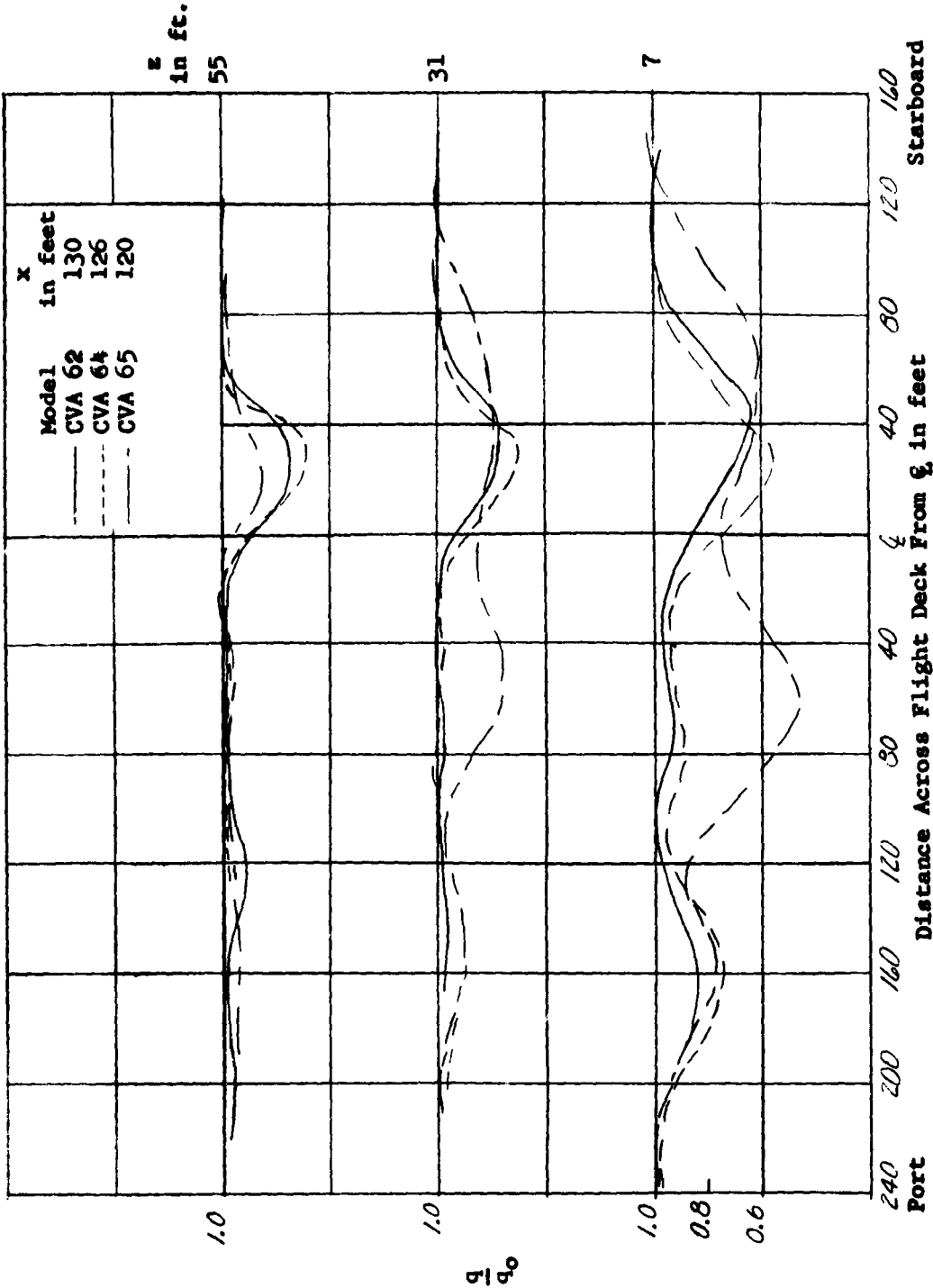


Figure 7 (Concluded)
(b) $x \approx 125$ Feet

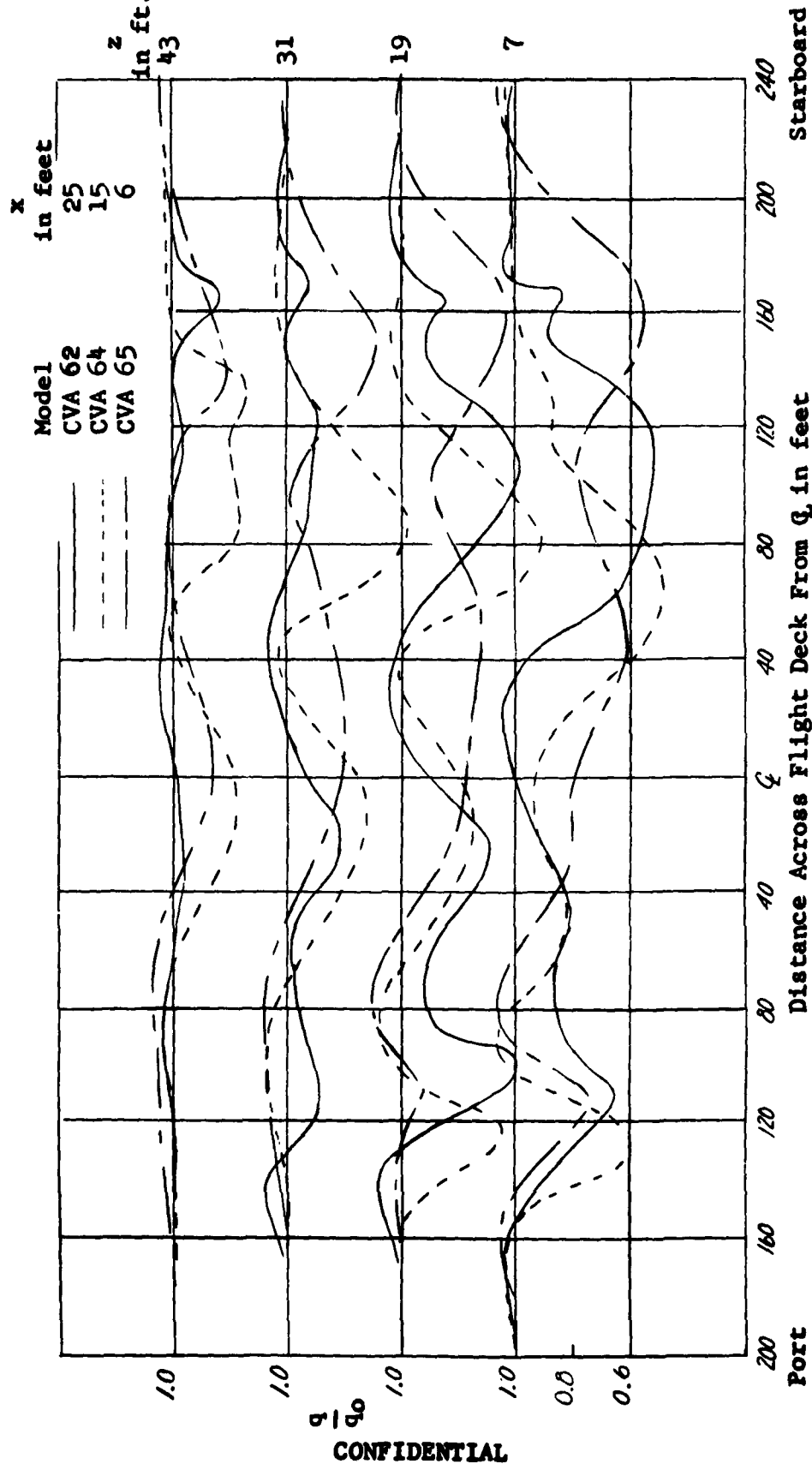


Figure 8 - Dynamic Pressure Ratios in the Wakes of Three Aircraft Carriers

With Relative Wind 10° Off Port Bow (i.e., Aligned With Angled Deck)(a) $x \approx 15$ Feet

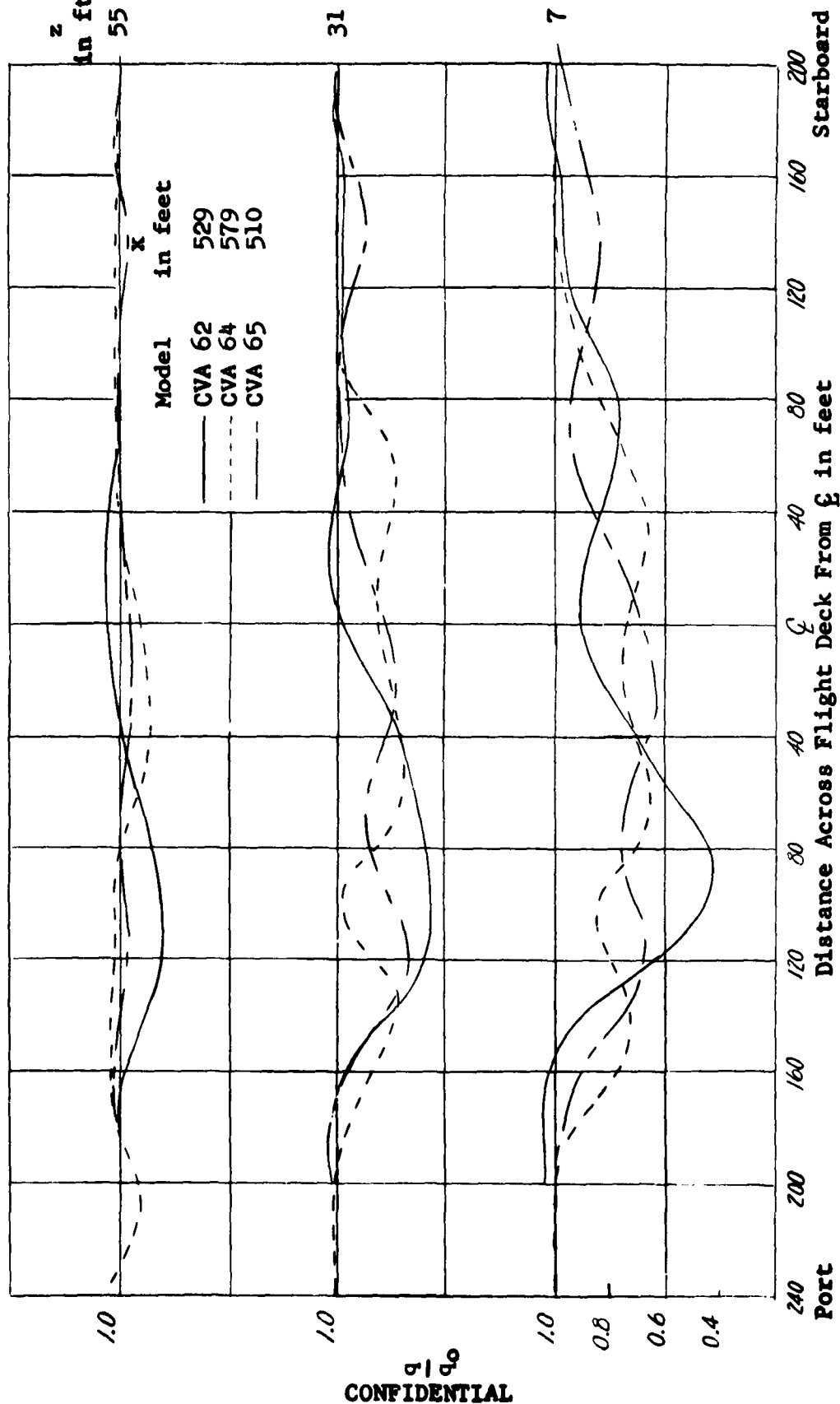


Figure 8 (Concluded)

(b) $x \approx 530$ Feet

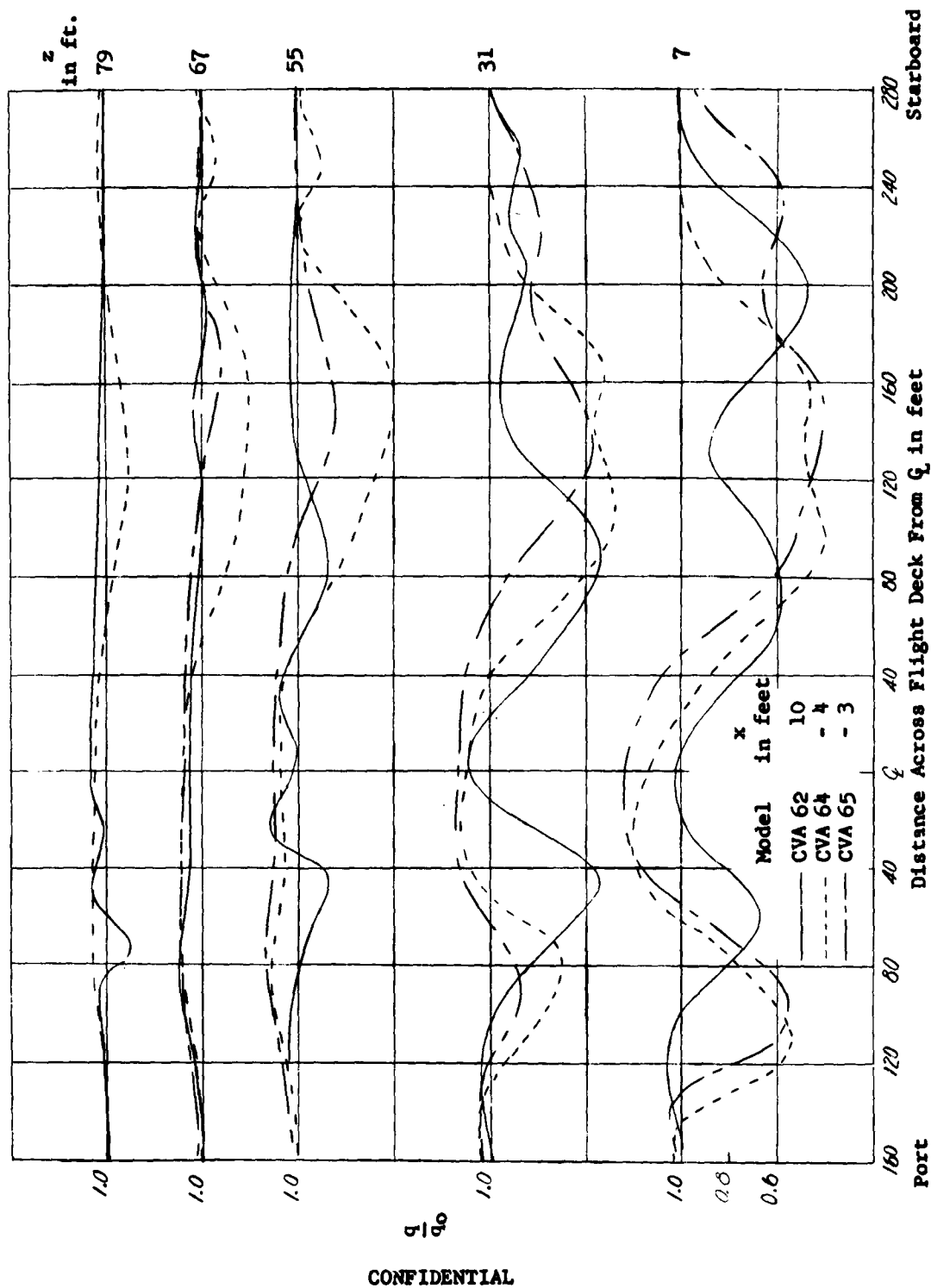
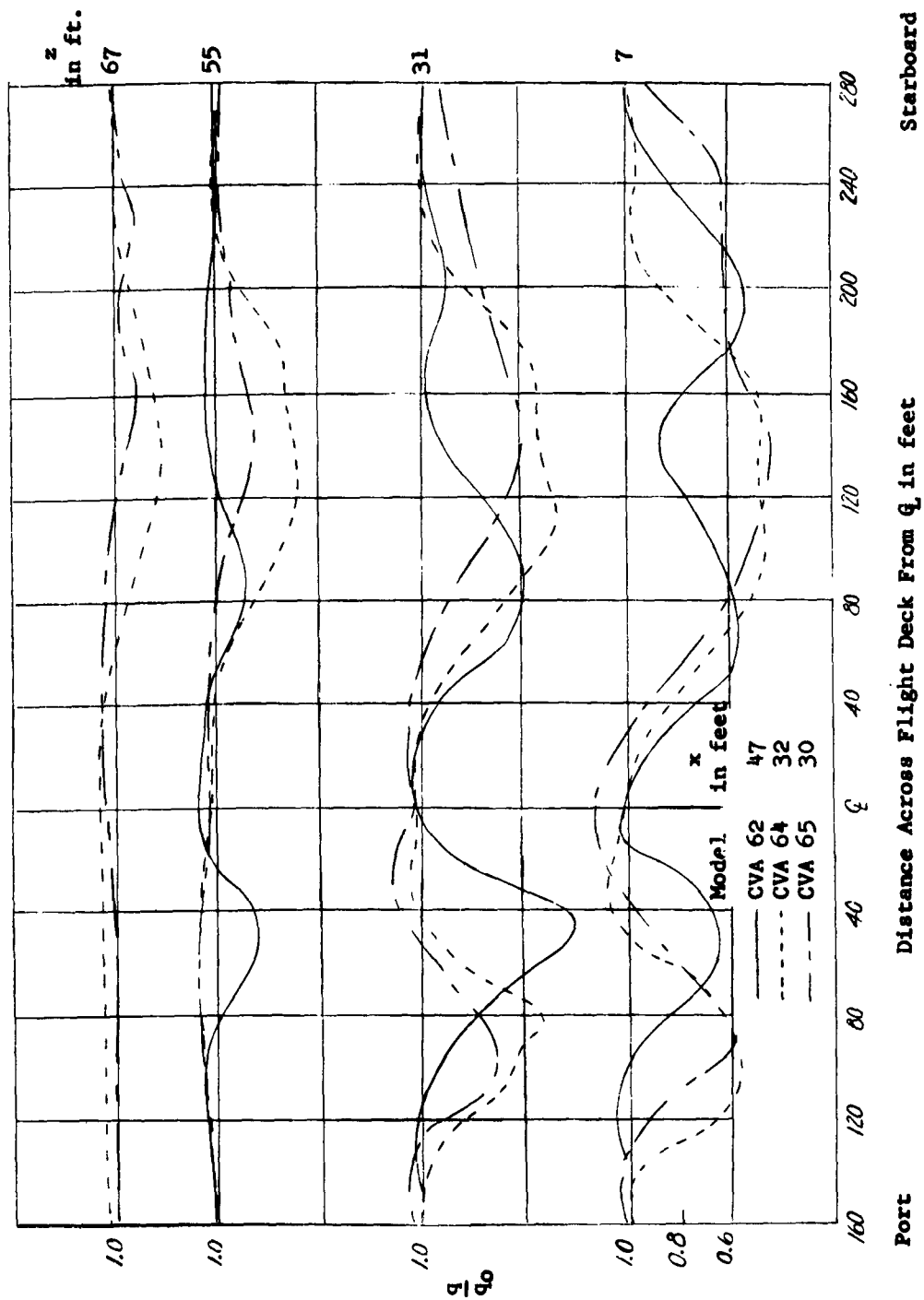


Figure 9 - Dynamic Pressure Ratios in the Wakes of Three Aircraft Carriers
With Relative Wind 20° Off Port Bow ($\psi = 20^\circ$)

(a) $x \approx 0$



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Figure 9 (Concluded)
(b) $x \approx 35$ Feet

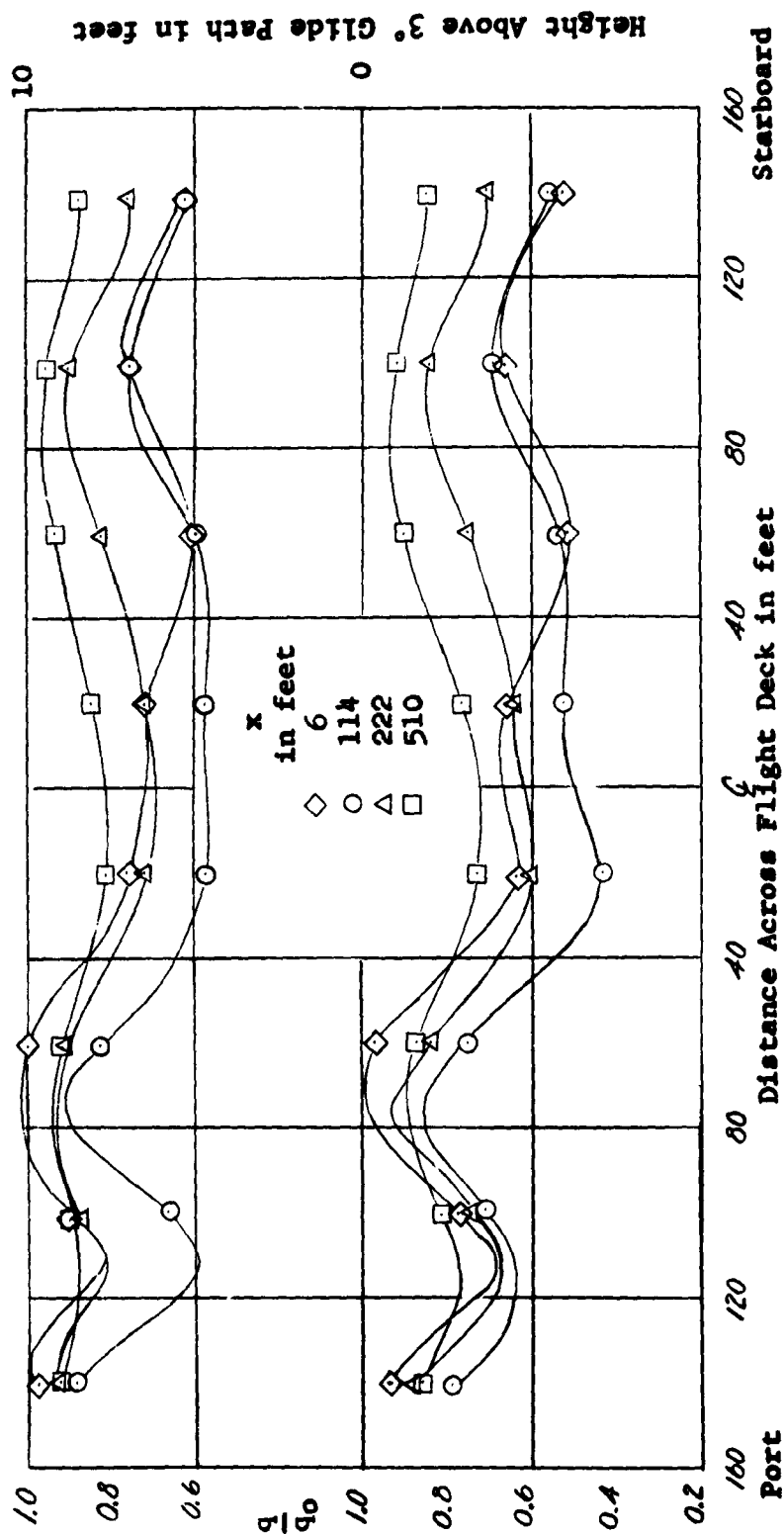


Figure 10 - Airflow Variation Along a 3° Glide Path Approaching the CVA 65 Carrier Deck, With Relative Wind Along the Center Line of the Angled Deck

(a) Variation of Dynamic Pressure Ratio

Note: The airflow direction is defined by ϵ and σ . Positive ϵ indicates airflow upward; positive σ indicates wind from the starboard.

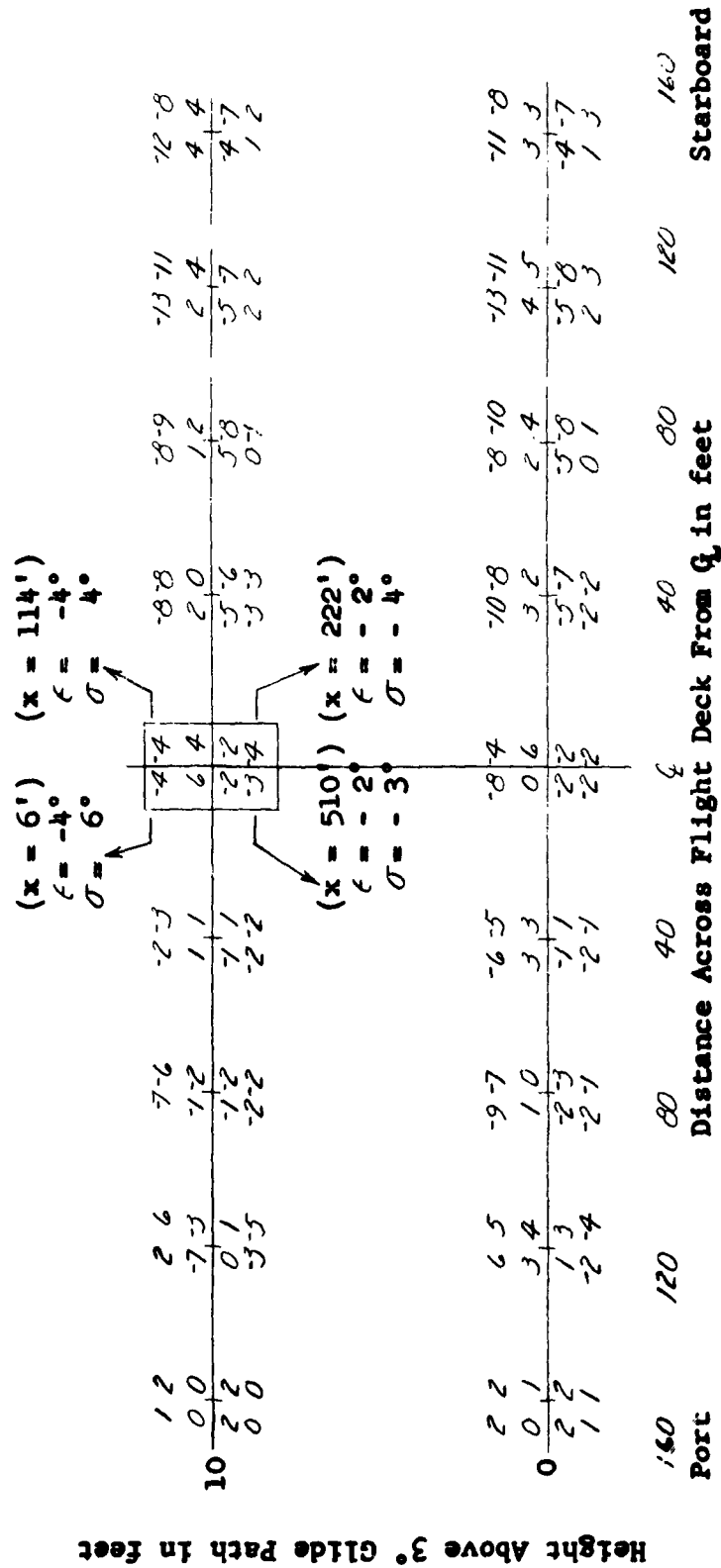
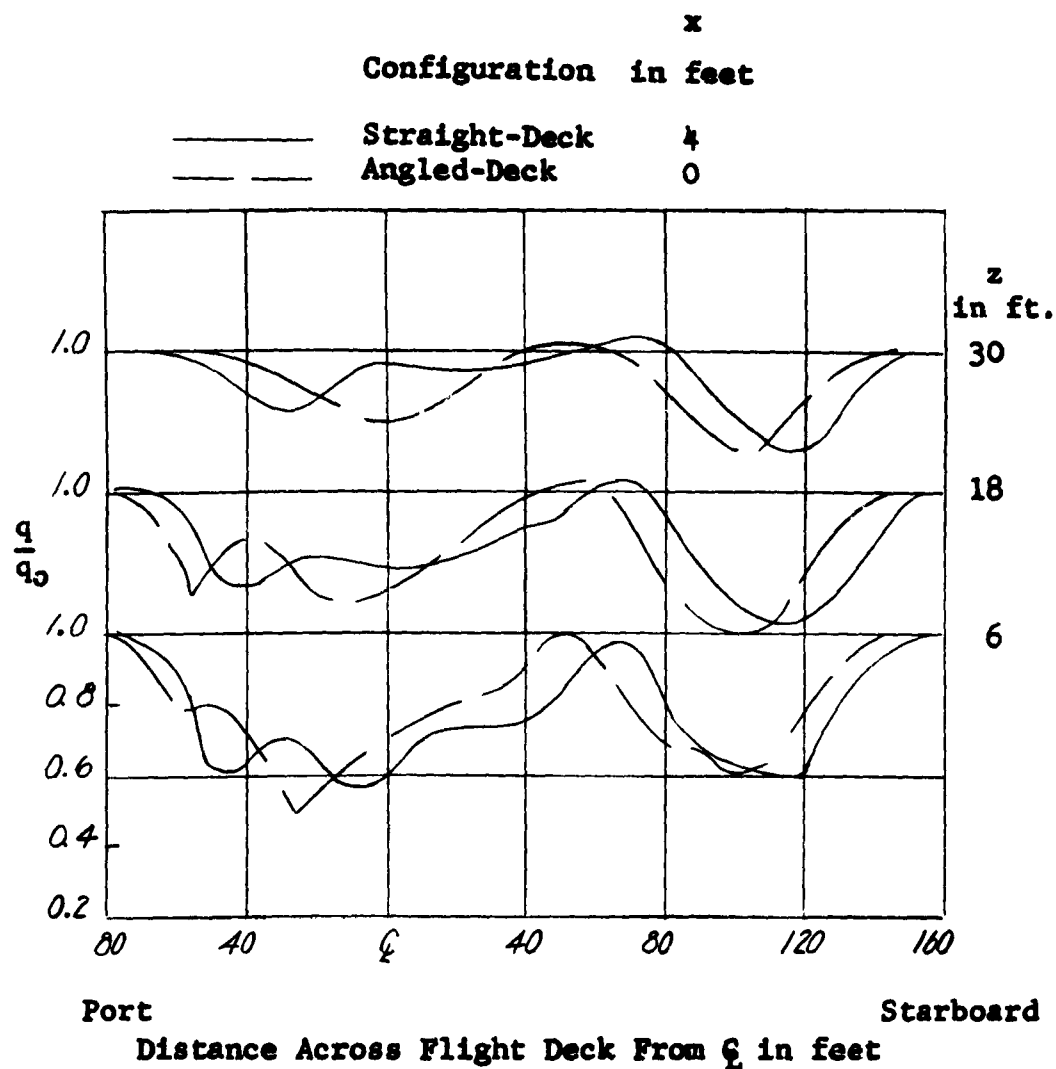


Figure 10 (Concluded)
(b) Variation of Direction of Airflow



**Figure 11 - Wakes of the Straight-Deck and
Angled-Deck Configurations of the CVS 36**

$$\psi = 10^\circ$$

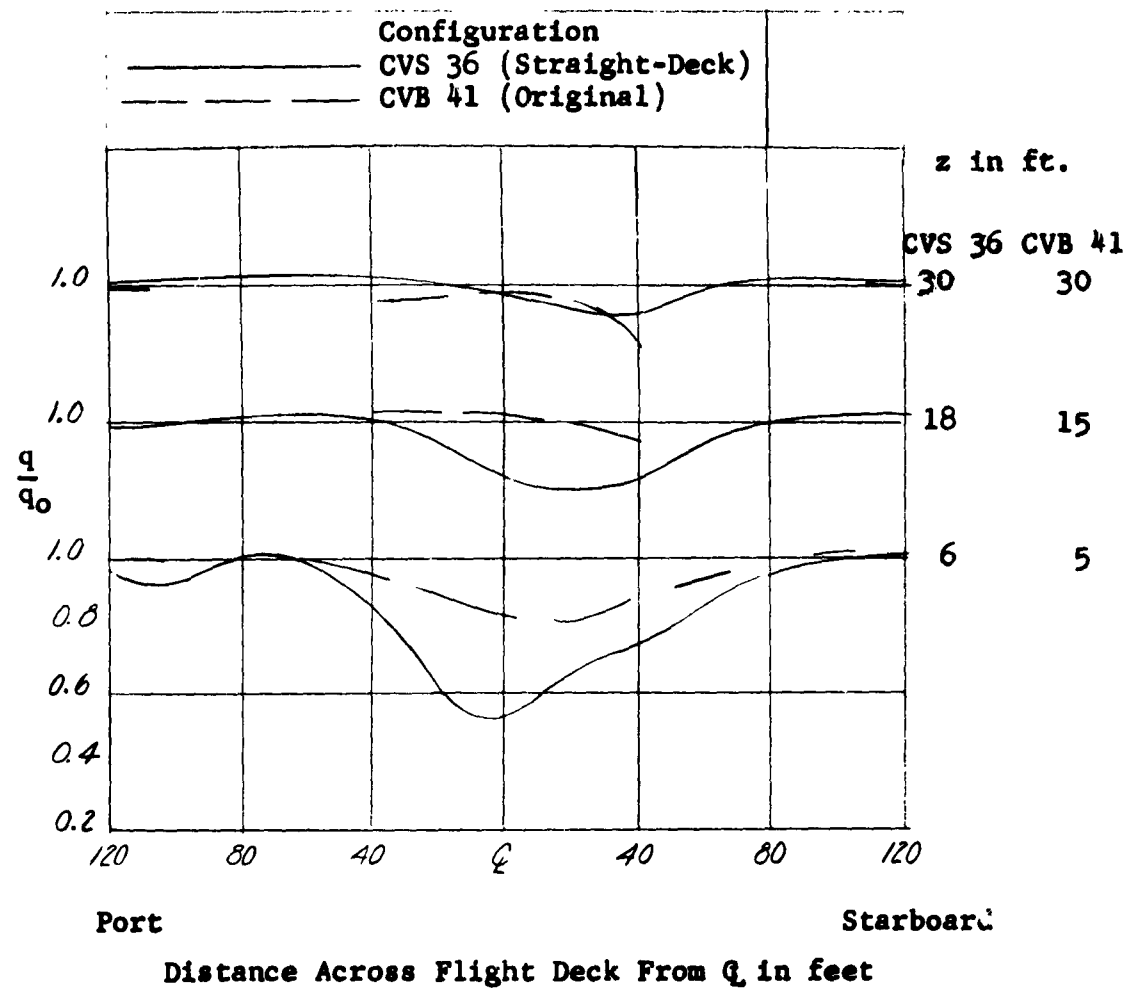


Figure 12 - Wakes of Two Carriers of Approximately
the Same Size and Configuration ($\psi = 0^\circ$)

(a) $x = 5$ Feet

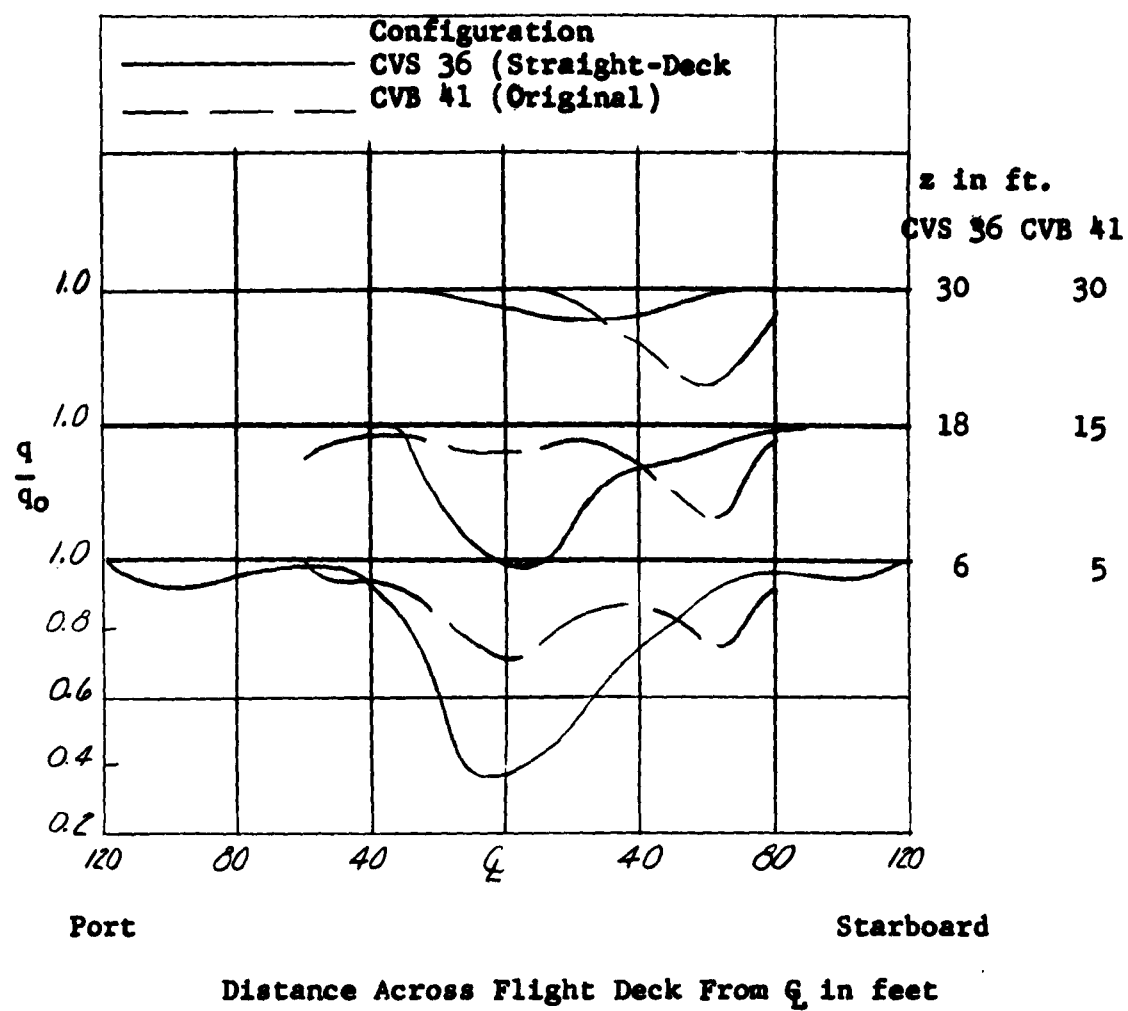


Figure 12 (Concluded)

(b) $x = 100$ Feet

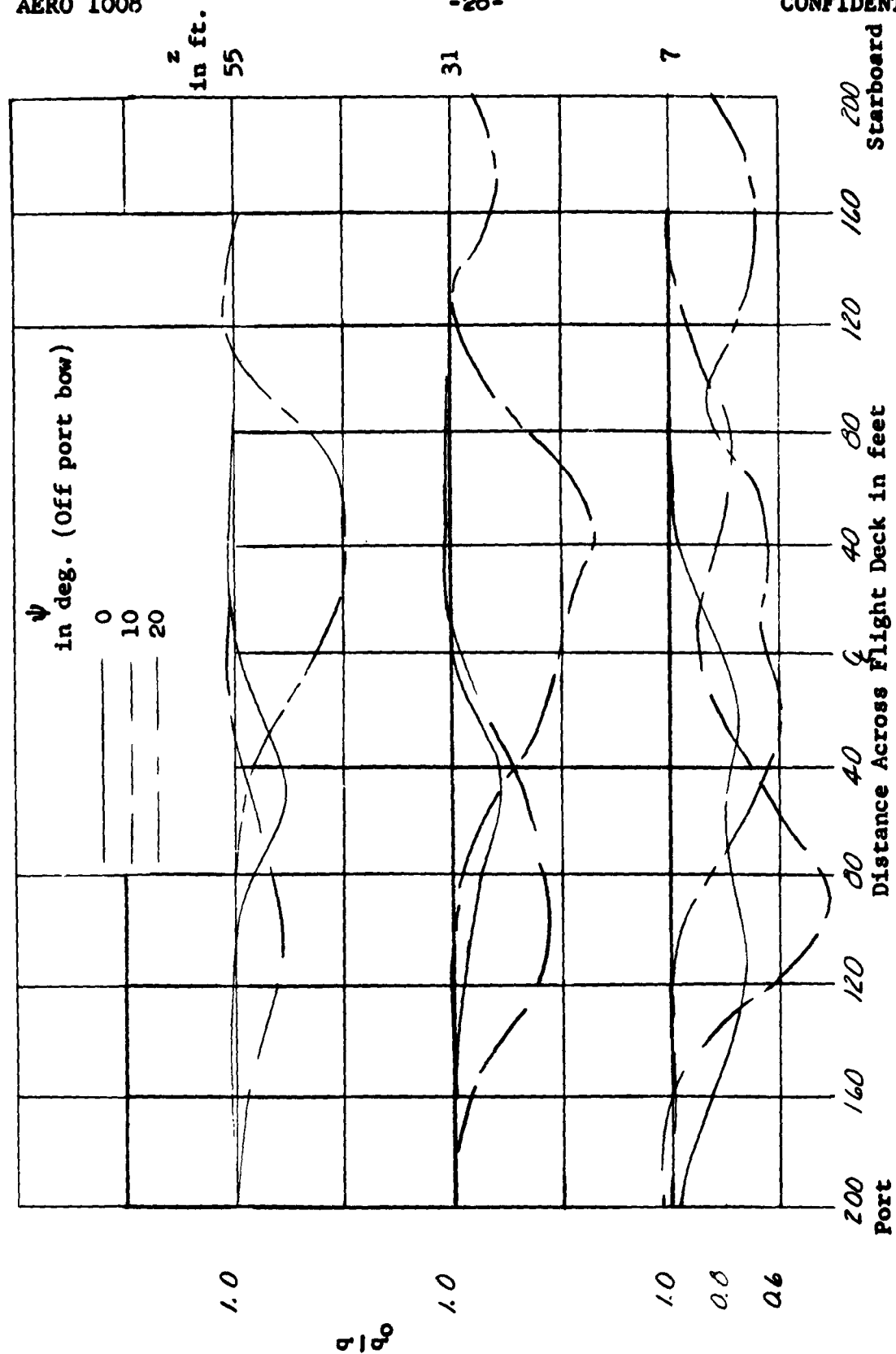
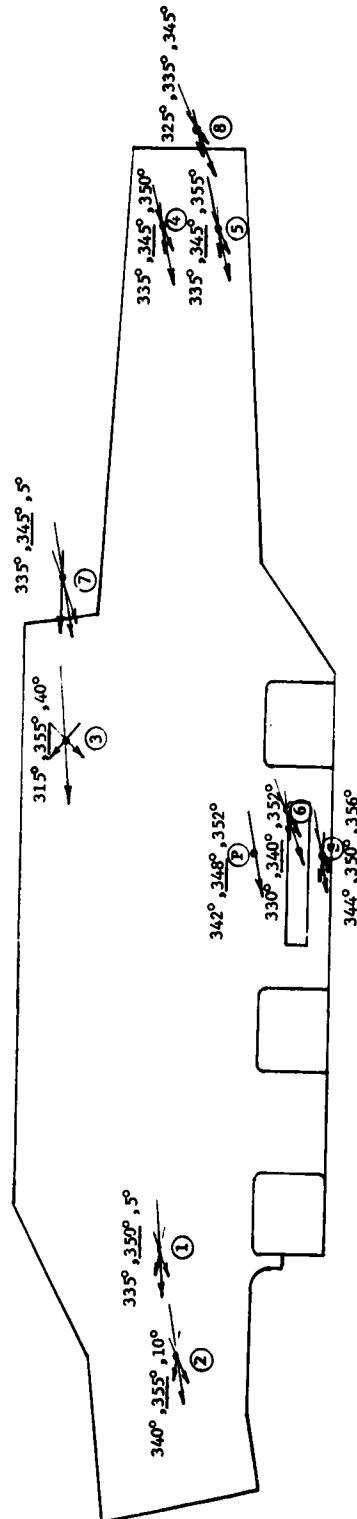


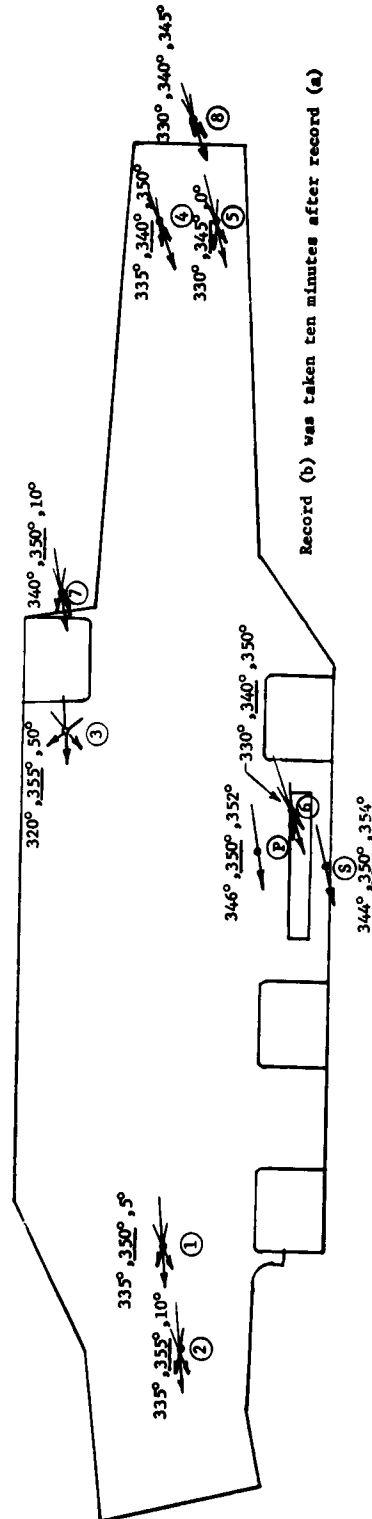
Figure 13 - Variation of the Wake of the CVA 62 With
Wind - Over - Deck Direction
x = 550 Feet



(a) Relative Wind Speed 20 Knots

Notes:
All readings were taken 6 feet above the deck, except (7), (8), and (9), which were taken at the yardarm.

Middle numbers (underlined>) are average values taken over a six-minute period. Other values are extremes in wind direction over the same period.



Record (b) was taken ten minutes after record (a)

(b) Relative Wind Speed 19 Knots

Figure 14 - Local Wind Directions on the CVA 61 Flight Deck.
Relative Wind Direction 350° .

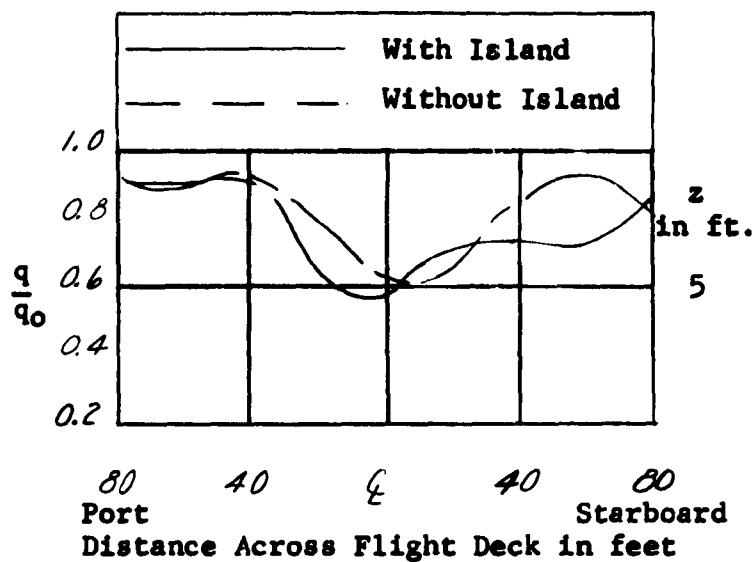


Figure 15 - Effect of the Island on the
Wake of the CVB 41 Carrier

$x = 150$ Feet; $\psi = 0^\circ$

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